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Field parasitoids of *Aonidiella aurantii* (Homoptera: Diaspididae) in Valencia (Spain)

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Abstract: California red scale, *Aonidiella aurantii* (Maskell) is considered a citrus key pest in Spain. Nowadays red scale is controlled using non-selective organophosphate pesticides. Fortunately, there is a trend throughout the world to minimise the use of insecticides in citrus and to promote the control of pests by the use of natural enemies. The first step previous to natural enemies releases is to know field parasitoid structure and to study parasitoids interaction. A survey was carried out in a citrus field in Valencia (East coast of Spain). As a result, two parasitoids were found: *Aphytis chrysomphali* and *Aphytis melinus*. *A. chrysomphali* was the predominant species. *A. melinus* was mainly found on third instar female scales and *A. chrysomphali* on male scales. The sex ratio was 1:1 for *A. melinus* and it was dependent on the host size. Only females of *A. chrysomphali* were found.
Key words: *Aonidiella aurantii*, *Aphytis chrysomphali*, *Aphytis melinus*, parasitoid structure, host stage, host size, parasitoid sex ratio.

Introduction

California red scale, *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae), is nowadays one of the most important economic pests in the Spanish citrus areas. The red scale is controlled by organophosphate insecticides and IGR treatments. Fortunately, the present tendency to control pests is focused on reducing chemical treatments and on looking for the most selective products. Furthermore, farmers who wish to develop an integrated pest management program are often interested in natural enemy releases.

The first step to develop or implement an IPM program with natural enemy releases is to study the parasitoid structure present in the field.

The most recent work about California red scale parasitoids in Spanish citrus areas was done between 1989 and 1991 (Rodrigo, 1993). Two species of *Aphytis* were found all through this monitoring: *Aphytis chrysomphali* (Mercet) that represented approximately 98% of red scale parasitoids and *A. melinus* DeBach that was just 2% (Rodrigo, 1993).

A. chrysomphali is an autochthonous parasitoid of the Mediterranean Basin. This parasitoid was first described from Mercet in Spain in 1912. Since that time, its presence in citrus areas has changed from being almost cosmopolitan to be clearly reduced as a consequence of the competitive displacement exercised by other species of the same genus. In California, no *A. chrysomphali* is reported (DeBach & Sundby, 1963), in Southern Italy it does not appear in the parasitoid catalogues of *A. aurantii* (Siscaro et al., 1999), in Cyprus it has been virtually displaced from the interior dry areas, and a similar situation has been observed in South Australia (Furness et al., 1983).

A. melinus was imported from India and Pakistan and introduced in southern California, where it displaced the other species of *Aphytis* (Rosen & DeBach, 1979). In Spain it was first introduced in 1976 from the "Station de Zoologie et de Lutte Biologique" of Antibes (France) to control *Chrysomphalus dictyospermi* (Morgan). Releases were intensified in 1985 when *A.*

aurantii was first detected as a pest. In 1996, more specimens of *A. melinus* were reintroduced from the Insectary of California, Riverside.

The aims of this work are to study red scale parasitoid structure and parasitoid fluctuation after ten years of the last field monitoring. Furthermore, the scale stage attacked by each parasitoid and parasitoid sex ratio are evaluated.

Material and methods

The monitoring was carried out every fifteen days from June 1999 to June 2000 in an orange field located at Alzira (Valencia) close to the first focus of *A. aurantii* as a pest. Red scale in this citrus grove was under biological control.

Ten shoots of 25 cm long, containing leaves, twigs and fruit (from fruit set to harvest) were picked up each time. The three different plant regions were examined individually. For the analysis, twigs and leaves were evaluated together and fruit was studied separately.

The recorded data were:

a) Parasitoid species (*A. melinus*, *A. chrysomphali* or *Aphytis* spp.)

b) Parasitoid stages (egg, larva, pupa, adult or exuvia), parasitoid number and parasitoid sex.

c) Host scale stage (second instar female, third instar female or male scale)

Immature stages were placed inside gelatine capsules until their emergence as adults or their death as immatures.

Adults were identified through microscope identification after preparing them on Hoyer's medium as explained by Rosen & DeBach (1979). Pupae and exuviae were identified using the different colour pattern that they have (Rosen & DeBach, 1979).

When parasitoids died as egg or larva, or pupa and exuvia were unrecognisable, they were added to *Aphytis* spp. column.

Results

Parasitoid species

A total of 3371 identified parasitoids were found throughout one year survey. The two parasitoid species obtained during the monitoring were *Aphytis chrysomphali* and *A. melinus*.

A. chrysomphali was the predominant species with 2619 specimens.

Parasitoid annual distribution

Annual distribution of all parasitoid stages (except exuvia) and parasitoid species was evaluated plotting separately leaves and twigs from fruits. A different tendency in parasitoid distribution was observed between both substrates. Whereas the parasitoid population on leaves and twigs remained constant all through the year, the parasitoid population on fruit showed a maximum in October and stayed with high values until the fruit harvest (Figure 1).

Parasitoid species abundance in the pupa and adult stage was analysed in both substrates. *A. chrysomphali* was the predominant species all through a year. *A. melinus* was also present all along the sampling period but remained at low numbers except for the summer months, when *A. melinus* was the most abundant species (Figure 2 and Figure 3).

Host scale

Host scale stage was different for both parasitoid species. *Aphytis* generally prefer to oviposit on third instar female scales because of their large size. The larger the scale, the larger is the resulting *Aphytis* offspring, or the more offspring can be produced per scale (Forster et al., 1995). Male scales can be considered as scales of medium size and second instar females as scales of small size. However, *A. chrysomphali* clearly preferred male scales, followed by second instar females and virgin third instar females. On the other hand, *A. melinus* preferred third instar females, followed by male scales and finally second instar females (Figure 4).

The same tendency was observed in both plant substrates.

Parasitoid sex ratio

A. melinus sex ratio was close to 1:1 whereas identified *A. chrysomphali* adults were practically always females (1 male out of 351 females).

A. melinus sex ratio was influenced by the host size and by the number of eggs laid on the host scale, as reported by Luck et al. (1982). *A. melinus* generally laid male eggs when the host scale was of small size and female eggs when the host scale was of large size (Table 1).

When more than one egg is laid in the same scale, several sex ratio combinations for *A. melinus* are possible. However, the unique parasitoid structure recorded in the field was 1:1 when two eggs were laid in the same scale. Host scale was always third instar female. Smaller scales could not hold more than one egg. If more than one egg was found in the scale, only would survive one.

On the contrary, *A. chrysomphali* sex ratio was independent of the host size and of the number of eggs laid on the scale. In all cases, only females were obtained.

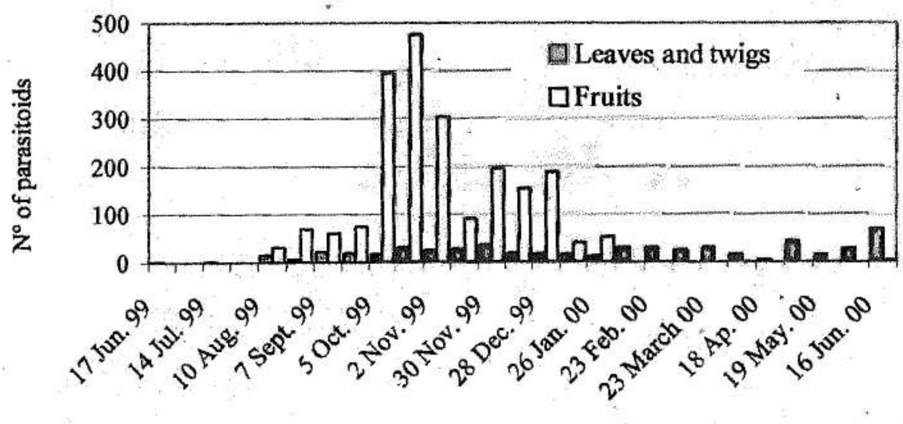
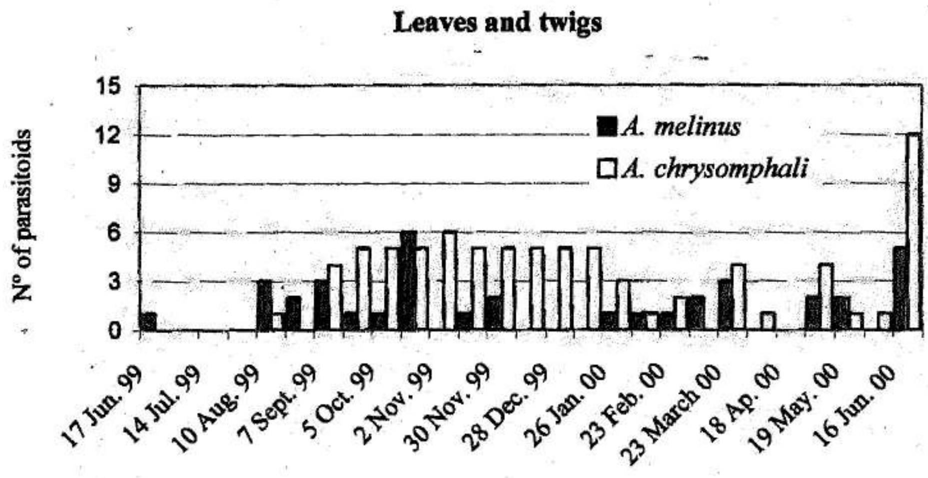
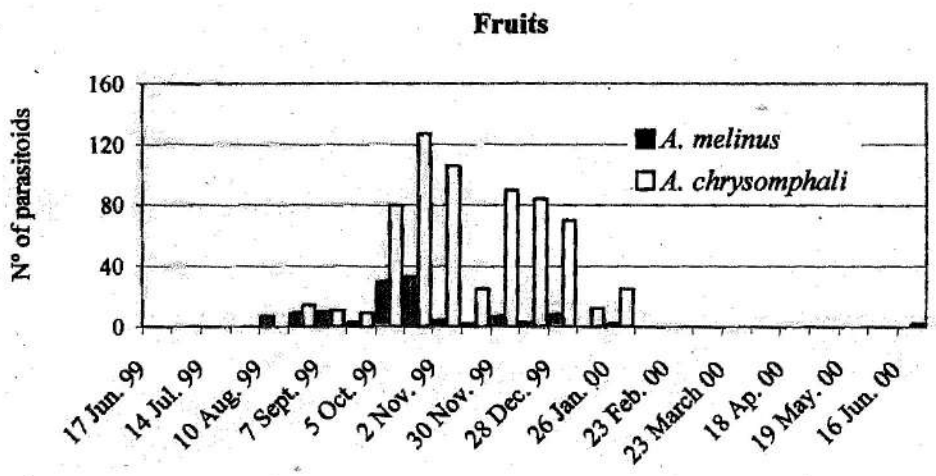


Figure 1. Annual distribution of *A. aurantii* parasitoids on two citrus plant substrates all through a year. All parasitoid species and parasitoid stages except exuvia are shown in this figure.





Figures 2 and 3. Parasitoid species abundance on California red scale, in the pupae and adult stage, in both citrus substrates for one year survey.

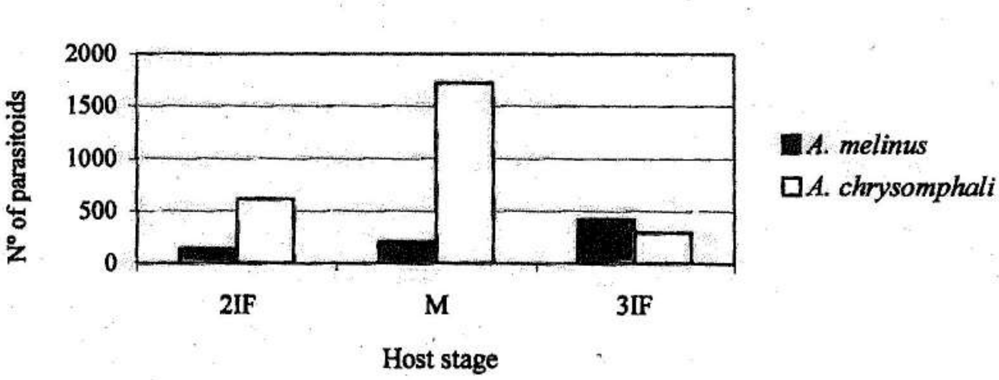


Figure 4. Red scale stage attacked by each parasitoid species. (2IF: Second instar female; M: Male scale; 3IF: Third instar female).

Host scale stage	*A. melinus*		*A. chrysomphali*	
	Total adults	*% male presence*	*Total adults*	*% male presence*
2IF	9	89	79	0
M	27	74	240	0.04
3IF	17	24	33	0

Table 1. Percentage of male presence from the total number of adults of each parasitoid species, depending on the host scale stage attacked. In *A. melinus*, as the host scale increases in size, the male parasitoid presence decreases (2IF: Second instar female; M: Male scale; 3IF: Third instar female).

Discussion

After ten years of the last field monitoring, *A. chrysomphali* is still the predominant parasitoid in the East coast citrus fields despite the mass releases of *A. melinus* and the expected competitive displacement exercised by *A. melinus* in other countries. This situation contradicts what happened in other places, where *A. chrysomphali* was complete or partially displaced by *A. melinus* after some years of coexistence (DeBach & Sundby, 1963; Furness et al., 1983; Orphanides, 1984; Siscaro et al., 1999).

It has been speculated that specimens of *A. melinus* introduced from Antibes were a different strain of this species (Troncho et al., 1992). If this hypothesis were accepted, and the strain that really gives good results in terms of parasitism rates was that introduced from California, it would be necessary to wait for a reversal of the situation in some years. However, the actual trend is that *A. chrysomphali* is still the most abundant parasitoid.

Furthermore our results dissent with those obtained by Troncho et al. (1992) and Hafez (1988) as far as *A. chrysomphali* does not show three clear peacks of activity and can be assumed that its presence is almost constant all through the year with a maximum in autumm.

A. melinus also appears throughout the year as *A. chrysomphali* except for the winter months when it disappears, and for the the summer months when it is more abundant than *A. chrysomphali*. Abdelrahman (1974a) described that *A. melinus* presents a better adaptation to extreme hot weather and *A. chrysomphali* to cold weather.

On the other hand, annual fluctuation of parasitoids clearly depends on the substrate. Parasitoid abundance is almost constant on leaves and twigs where a stable scale population can be found. However, scale population on fruit experiments an exponential increase, from the moment they reach the fruit on the first generation (Rodrigo & García-Marí, 1994) and, as a consequence, the parasitism rate also shows a quick rise confirming the density dependence response. McLaren & Buchanan (1973) observed a similar density-dependence trend between scale and parasitoid density.

The preferred host stage by *A. chrysomphali* is the male scale. The same result was obtained by Abderahman (1974b) and Rodrigo (1993). Smith (1978) also pointed that *A. chrysomphali* parasitizes more frequently second instar female, second instar male and prepupa. Third instar scale is the scale stage preferred by *A. melinus* confirming the results obtained in laboratory by Abdelrahman (1974b) and Forster et al. (1995).

All throughout one year of field monitoring, *A. melinus* sex ratio was close to 1:1 and it was clearly variable depending on the host size. Luck et al. (1982) reported that *A. melinus* is a biparental species that can control the sex of its progeny depending on the host size. However, *A. chrysomphali* is an uniparental species and male presence occurs in a really low percentage in the field (Rosen & DeBach, 1979). During the monitoring, almost all *A. chrysomphali* adults obtained were females and its presence was independent of host size. This fact gives *A. chrysomphali* advantage when the extreme temperatures prevail over the arrhentokous *A. melinus*, because the population of *Aphytis* would be extremely low. *A. chrysomphali* starts reproducing female progeny a few hours after emergence, whereas female *A. melinus* will produce only male progeny until fertilization. This would reduce the possibility of *A. melinus* of leaving female progeny when killed by extreme temperatures (Abdelrahman, 1974a).

The next step is to study the relationship between percentage parasitism and percentage of suitable scales for parasitoid reproduction to determine parasitism rate.

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